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A SOVIET THREE-WINDING MEASURING CONVERTER FOR MEASURING HIGH DIRECT CURRENTS

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/Figures referred to are appended./

The development of industry, particularly chemistry and the metallurgy of nonferrous metals, has greatly expanded the circle of enterprises whose main technological process requires the use of high dc power at comparatively low voltages (100-800 v) and currents reaching thousands and tens of thousands of amperes in one conductor.

These currents must be measured with great accuracy in order to supervise correctly the technological process, to effect measures that save electric power, and to establish norms for energy consumption. The measurement of direct currents is also frequently necessary for automatic regulation purposes.

Only a measuring instrument which can be checked without special difficulty under plant laboratory conditions or in the laboratory of the administration of the Committee on Measures and Measuring Instruments will be of practical value. It would also be very desirable to be able to produce the main elements of the measuring instrument directly in the electric shop of the plant.

The measurement of direct currents with the help of multicurrent shunts cannot completely satisfy the requirements of industry because of the restricted upper limit of measurement. In addition, the production of measuring shunts requires high-quality manganin and a specially developed technology and therefore cannot generally be done in the electric shop of a plant. This article contains a description of a three-winding static measuring converter (a dc "transformer") designed for the measurement of high direct currents.

The basic characteristics of this converter are: possibility of checking the converter at currents of only a fraction of a percent of rated current; use

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of cold-rolled electrotechnical steel, mark KhVP, for the magnetic system, instead of expensive alloys of the permalloy type; possibility of producing the main element of the converter in the electric shop of a plant; and measurement of direct currents of 5-10 ka and above with an accuracy of 0.5-1.5%.

The measuring converter was developed, designed, built, and studied as a result of the joint work of a scientific-research institute and an electrometallurgical plant.

The operation of the measuring converter is based on the well-known effect of proportionality of a rectified alternating current to the magnetizing current in a circuit containing two windings, connected in series, with the current flowing in opposite directions in each, placed on magnetic circuits magnetized by the current to be measured (Figure 1).

In contrast to existing dc transformer circuits, an additional winding is placed on each core for checking purposes and for stabilizing the secondary current when the ac line voltage fluctuates.

As Gorfman has shown, a multiturn winding spaced uniformly along an annular magnetic circuit creates a magnetic field which is identical to the field of a bus bar passing through the opening of this magnetic circuit. Consequently, by passing a direct current through the third winding, which creates the same magnetic field as the measured current passing through the bus bar, we can reproduce for the converter the operating conditions holding in the measurement of a high current.

The current required in the check winding to create checking conditions equivalent to the operating conditions can be determined from the relationship:

$$I_n = I_1 \frac{w_1}{w_n}$$

where I_n and I_1 and w_n and w_1 are respectively the currents and number of turns of the check and primary windings.

With regard to the distortion introduced by the fields of adjacent conductors, which are always present when the converter is used under production conditions, these do not introduce any substantial error in the measurement by disturbing the distribution of magnetizing force along the perimeter of the magnetic circuit, since the distribution of the induction in the steel remains practically uniform.

The truth of the preceding statement can be demonstrated by comparing the results of a theoretical determination of the greatest nonuniformity δ in the distribution of magnetizing force when a conductor is placed within the opening of the magnetic circuit and outside of it. The results of such a determination are shown in Figure 2. The curves show that a return wire placed at a distance a from the center of a magnetic circuit of radius r creates at $\eta = \frac{a}{r} = 2$ the same nonuniformity as the outgoing wire when placed within the limits of half the radius of the magnetic circuit. Placing the outgoing wire within the ring, as was demonstrated experimentally, will not affect the accuracy of the current measurement if a method is used which provides for compensation of the magnetic field of the bus bar by the field of a uniformly distributed winding, i.e., will not introduce distortions in the field created by the bus bar.

However, despite the identity of the magnetic fields created by the bus bar conductor and the multiturn winding, the relationships between the direct current and the current in the secondary winding will be different under check conditions than in the actual measurement of a high current, unless special

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measures are taken. This is explained by the stronger transformer coupling between the secondary and check windings, which causes considerable even-harmonic emf's to arise in the check winding circuit.

The development of a checking circuit which would eliminate the flow of ac in the dc circuit is very difficult in practice. Suppression of the ac requires inclusion in the check winding circuit of a choke coil with high inductance designed for the total current of the check winding.

The three-winding converter permits one to create equivalent conditions in checking and in measurement by a different method, namely, by closing the check winding through a certain impedance under operating conditions. In this way, the parameters of the circuit for the even-harmonic currents are maintained the same under operating conditions as in check operation. Under operating conditions, the check winding helps to stabilize the instrument readings when the supply voltage fluctuates (see appendix).

In calculating the dimensions of the magnetic circuits of the converter, the determining factor is the possibility of placing the winding copper and the bus bar conductor in the opening of the core for a given permissible current density in the bus bar conductor and in the windings. As experiments have shown, the number of turns of the secondary winding for a converter with cores of KhVP steel can be determined from the formula:

$$w_2 = w_1 \frac{I_1}{I_{2av}} .$$

For the secondary winding, a voltage should be selected which will provide the minimum dependency of secondary current on voltage fluctuations. This can be achieved by selecting an induction (voltage) amplitude such that its change will cause a minimum current change, i.e., and amplitude in the region of the vertical sections of the hysteresis loop. By selecting a value of induction greater than saturation induction, we can, to a certain degree, compensate for the lack of proportionality between the number of turns on the primary and secondary windings and the currents in them. This lack of proportionality results because the magnetization curve differs from the ideal curve.

A converter with an upper limit of measurement of 5,000 amperes was designed and built for the measurement of high direct currents (Figure 3). The primary current of 5,000 a corresponds to a secondary current of 5 a and a current of 20 a in the check winding.

Curves were taken describing the behavior of the converter under double magnetization (Figure 4) [by currents in the primary and in the check windings]. Complete identity of the magnetic properties of the magnetic circuits was attained for a current in the check winding (I_n) of 4 a. The dependency of the voltage across the secondary winding on the average current in it (I_{av}) for different values of the magnetizing current is given in Figure 5. On another scale, these curves show the dependency of the total induction on the average value of field intensity. The curves are parallel to one another over a considerable range.

By changing the impedance in the check winding circuit, it was established that for a certain critical value $z_n > z_{ncr}$, the current I_{2av} reaches a certain value I'_{2av} and does not change with a further change of z_n.

Figure 6 shows the change of the difference of the currents $\Delta I_{2av} = I_{2av} - I'_{2av}$ as a function of z_n for various magnetizing currents. It was found that $z_{ncr} = 50\Omega$. In experiments under plant conditions, when the measured current reached 4,700 a, the same value was established for z_{ncr}, and the check winding was closed through this impedance. An increase of z_n above $50\,\Omega$ under actual operating conditions will not cause a change of I_{2av}.

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It has also been shown experimentally that in the measurement of the rated current, a change of ac voltage by 15% will cause a change of the instrument readings of only 1%. The change in the resistance of the secondary circuit caused by heating of its elements is less than 3 ohms and does not affect the instrument readings.

It was noted previously that magnetization of the converter by the check winding is completely identical to its magnetization by a bus bar carrying current. Consequently, if in checking we make the impedance of the check winding circuit equal to the impedance through which it will be closed when the converter is used in production conditions, and, if $I_1 w_1 = I_n w_n$, the checking conditions will be equivalent to the operating conditions, and we can speak of checking the converter in an equivalent circuit

The measuring converter IP 5000/5 was checked by passing direct currents of different magnitudes through the check winding. The current in the check winding and in the secondary winding was measured by well-calibrated moving-coil instruments whose error did not exceed 0.2%. As a result of more than 200 measurements (10-12 measurements for each value of check winding current), the relative mean-square errors σ_0 and the relative errors of the measurement ε_0 were calculated. Some of these are shown in the following table:

I_1 (calculated) (a)	I_{2av} (a)	σ_0 (%)	ε_0 (%)	$k = \frac{I_1}{I_{2av}}$
1000	0.995	--	--	1006
1505	1.440	0.4	0.1	1045
2255	2.150	0.3	0.06	1049
2762	2.620	0.2	0.04	1054
3515	3.327	0.3	0.06	1056
4260	4.013	0.3	0.05	1061
4655	4.390	0	0	1061
5250	4.950	0	0	1060

For a change of current in the check winding corresponding to a current change in the bus bar from 2,000 to 5,200 a, σ_0 did not exceed 0.4% and ε_0, 0.09%. For small current values, these errors increased and σ_0 reached 0.6 to 1%.

The conversion coefficient k differs from the theoretical value $k = \frac{w_2}{w_1}$ by 5%, and by 1% from the average value in the interval 2,000-5,000 a. If a corrected value for the conversion coefficient is used, it can be considered that its deviation in the range 2,000-5,000 a does not exceed 0.5%.

The results of checking in an equivalent circuit the error of measuring a high current with the help of the converter, making corrections for each measurement, established that the error lay within 0.5% of the measured value. When the IP 5000/5 is used without a correction curve, its error is less than ±1.5% within the range of 2,000-5,000 a (normal operating range).

To confirm the correctness of the check of the measuring converter in an equivalent circuit, the results of measuring a direct current obtained with the IP 5000/5 were compared with the results of measuring the same current with the help of a calibrated shunt. The calibrated shunt was studied in the Electromagnetic Laboratory of the Sverdlovsk Affiliate of the All-Union Scientific-Research Institute of Metrology by a method developed in the laboratory. The deviation of the results was less than 0.6% for currents from 2,000 to 4,500 a.

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The results of measurement show negligible dependency on temperature and frequency of the alternating current. No changes in the instrument readings were observed for a temperature change of the building from $+12^\circ$ to $+18^\circ$ C, of the windings from $+12^\circ$ to $+23^\circ$ C, and of the rectifier from $+12^\circ$ to $+20^\circ$ C. No change in the readings was observed for frequency changes of 2-3 cycles.

The converter unit which was built has been installed in the converter substation of the plant.

Summary

1. For measurements of high direct currents, a satisfactorily operating measuring converter can be built with magnetic circuits of cheap mark-KhVP steel, instead of with permalloy.

2. It is efficient to use a third check winding, connected through an impedance under operating conditions, for checking the converter and maintaining equivalent checking and operating conditions.

3. The measurement error of a 5000/5 a converter does not exceed $\pm$ 0.5% if corrections are used, and $\pm$ 1.5% if a constant conversion coefficient is used.

APPENDIX

The circuit for connecting the windings of one magnetic circuit of a converter is shown in Figure 7. The current to be measured, produced by a voltage U_{11}, flows in the primary winding w_{11}. We can consider that no alternating current flows in the circuit of this winding. This assumption, approximately valid, is based on the fact that $w_1 = 1$ in the bus bar converter, and the inductance of the circuit may be considerable. The secondary winding with a number of turns w_{21} is connected to a sinusoidal voltage U_{21}. We close the check winding through a certain impedance z_n; alternating current flows in this winding.

By considering that there is no alternating current in the winding w_{11}, we can consider its effect on the circuit, taking the current in the check winding into consideration.

The processes in a measuring converter having three windings on each magnetic circuit can be described by three differential equations:

$$E_1 = I_1 R_1 + L_1 \frac{dI_1}{dt} \qquad [1]$$

$$U_2 = i'_2 R_2 + L \frac{di'_2}{dt} + W_2 \frac{d}{dt} (\phi_1 + \phi_2) \qquad [2]$$

$$0 = I_n R_n + L_n \frac{dI_n}{dt} + W_n \frac{d}{dt} (\phi_1 - \phi_2) \qquad [3]$$

These differential equations also hold for a two-winding "dc transformer" if we consider that the measured current circuit consists of two parts, i.e., the circuit of the current I_1, in which alternating current does not flow, and some second circuit in which flow alternating currents caused by transformer coupling of the windings.

Remembering that the curves for the fluxes ϕ_1 and ϕ_2 are displaced by a half period relative to each other and that one is thus a mirror image of the other, they can be represented in the form of the series.

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$$\phi_1 = A_0 + \sum_{k=1}^{k=\infty} A_k \sin (kwt - \alpha_k),$$

$$\phi_2 = A_0 + \sum_{k=1}^{k=\infty} (-1)^{k+1} A_k \sin (kwt - \alpha_k) \qquad [4]$$

To obtain an idea of the operation of the check winding, we can solve equations [1], [2], and [3], assuming that the leakage flux of the windings is zero and that the measured current does not vary with time. Considering the effect of the magnetic flux created by the current I_n, we obtain the following expression for the current in the secondary winding:

$$I_2'' = \frac{Um}{R_2} \cos (wt + \phi) - \frac{2\omega w_2}{R_2} [\varepsilon_1 \cos (\omega t - \gamma_1) +$$

$$+ 3a_3 \cos (3\omega t - \alpha_3) - 5a_5 \cos (5\omega t - \alpha_5) + \ldots \qquad [5]$$

$$- 2a_2' \sin (2\omega t - \alpha_2) - 4a_4' \sin (4\omega t - \alpha_4) \ldots];$$

$$A_2' = - \frac{4w_n \omega}{R_n} a_2 \xi \; ; \quad a_4' = - \frac{8 w_n \omega}{R_n} a_4 \xi,$$

where ξ is a coefficient proportional to the magnetic permeability at the given current, R_n is the ohmic resistance of the check winding circuit, R_2 is the resistance of the secondary winding, and U_m is the amplitude of the secondary voltage.

Expression [5] shows that the current in the secondary winding depends on the relationship of all the parameters of the converter and that a change in the resistance R_n is reflected in the magnitude of i_2''. From the same expression, we can establish certain stabilizing properties of the additional winding; the terms determining i_2'', which depend on the line voltage (the coefficients a and a'), have different signs in expression [5]. Their values change when the voltage fluctuates, but the algebraic sum remains practically constant.

The stabilizing effect depends on the resistance of the check winding circuit to currents caused by higher harmonics.

For example, the change of secondary current was only 0.86% when the supply voltage fluctuated by 25% (200-160 v) with negligible inductance in the check winding. With more impedance in the check winding circuit, the current variations reached 1.4% for the same voltage fluctuations (from the results of testing a measuring converter at currents up to 15,000 a). If the check winding were not used, fluctuations of the supply voltage would have a much greater effect.

BIBLIOGRAPHY

1. Tolstov, Yu. G., "The Operation of DC Measuring Transformers Under an Active Load," Izvestiya Akademii Nauk SSSR, OTN, No 4, 1948.

2. Peretts, V. B., "The Effect of the Parameters of the Measuring Circuit and the Form of the Magnetization Curve Upon the Operation of a DC Measuring Transformer," Elektrichestvo, No 2, 1950.

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3. Gorfman, A. I., "Measurement of High Direct Currents With the Help of DC Magnetization of a Transformer," Dissertation at the All-Union Scientific-Research Institute of Metrology, 1940.

4. Bessonov, L. A., Electric Circuits With Steel, Gosenergoizdat, 1948.

[Appended figures follow.]

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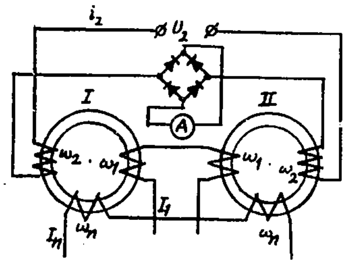

Figure 1. Schematic Diagram of the Three-Winding Measuring Converter

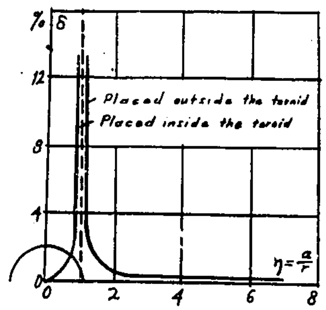

Figure 2. Nonuniformity in the Distribution of Magnetizing Force When the Bus Bar is Placed Inside and Outside the Core

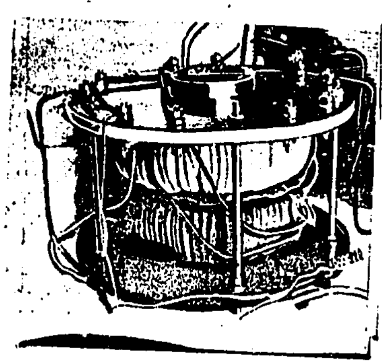

Figure 3. External View of the IP 5000/5 Converter

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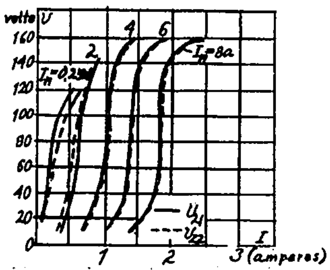

Figure 4. Curves of Double Magnetization

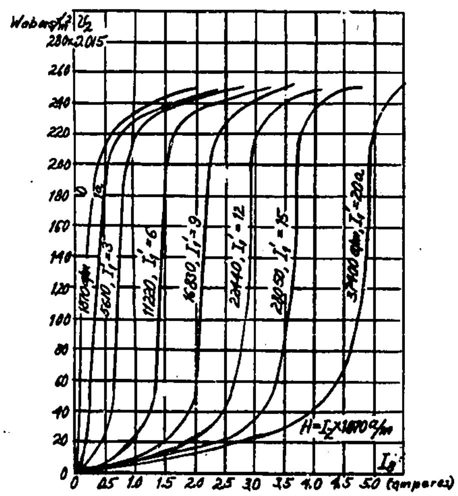

Figure 5. Dependence of Voltage in the Secondary Winding on Secondary Current and Magnetizing Current

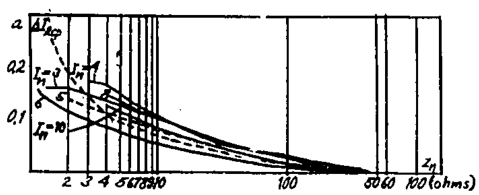

Figure 6.

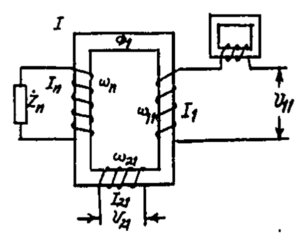

Figure 7. Connections for One Magnetic Current

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